STORAGE MECHANISMS AND THE REDUCTION OF POST-HARVEST LOSS IN FRESH CASSAVA ROOTS: A CONCEPTUAL REVIEW

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Abstract

The study on storage mechanisms and the reduction of post-harvest loss for fresh cassava roots: a conceptual review was motivated by the massive post - harvest loss experienced by cassava farmers in Idomi, Yakurr Local Government Area of Cross River State. These losses have hindered the effective commercialization of the crop in the area. Based on the above, the study was aimed at examining the effect of storage mechanisms such as waxing, field clamps storage, storage in boxes lined with moist sawdust and storage in plastic film wraps / bags. These storage mechanisms were examined in order to determine their effect in reducing post - harvest loss for fresh cassava roots. In line with the above, exploratory research design was adopted in order to enable the researcher obtain empirical and qualitative information as regard the subject under investigation. Hence, it was revealed that the storage mechanisms such as waxing, field clamps, storage in boxes lined with moist sawdust and storage in plastic film wraps / bags all have a positive effect in the reduction of post - harvest loss for fresh cassava roots. Hence, it was concluded that storage mechanisms such as waxing, field clamps, storage in boxes lined with moist sawdust and storage in plastic film wraps / bags should be adopted and properly implemented in Idomi; because they help in the reduction of post - harvest loss for fresh cassava roots by extending the shelve life of the crop thereby promoting the marketing and commercialization of the crop.

Keyword: Storage mechanisms, waxing, field clamps, boxes lined/moist sawdust, plastic film wraps/bags storage, post - harvest loss

Introduction

Cassava (*Manihot esculenta* Crantz) is a staple crop and remains a staple food for hundreds of millions of people in the tropics and subtropical belts as well as a feedstock for numerous industrial applications, including food, feed and starch (IFAD/FAO 2001). The crop according to Burrell (2003) belongs to the Euphorbiaceae family , and reports have it that the crop originated from South America and was domesticated between 5000 and 7000 years B.C.(Olsen & Schaal, 2001). The first import of cassava to Africa was by the Portuguese from Brazil in the eighteenth century, but now cassava is cultivated and consumed in many countries across Africa, Asia and South America (Nhassico, Muquingue, Cliff, Cumbana & Bradbury 2008; FAO 2013). Cassava as a staple crop in Africa, provides more than 10 percent of the daily dietary caloric intake to about 300 million people In 15 African countries like Nigeria, Ghana, Congo, Uganda, ecetera (Mpoko, 1999), and as such; it is considered as the fourth most important source of dietary energy in the tropics after rice, sugar and maize; the second in Africa and the ninth worldwide (FAO, 2004). The above consideration of cassava as the fourth most energy rich food source remains attributed to its high (> 70 %) carbohydrate content (Falade & Akingbala, 2010).

According to Onyenwoke and Simonyan (2014) cassava which is a perennial woody shrub with an edible root, that grows in tropical and subtropical areas of the world is cultivated throughout the year, and according to Lyer, Mattinson and Fellman, (2010), the cultivation and processing of Cassava provide household with food security, income and employment opportunities to over 500 million people in Africa, Asia and America. In line with the above, Lebot (2009) maintained that cassava as a food crop is consumed by 800 million people worldwide because the crop is tolerant to low soil fertility, drought and most pest and diseases with no critical date of harvest. The above attributes have according to FAO (2009) made cassava a crop of primary importance because of its potential to increase farm incomes, reduce rural and urban poverty and help ensure food security of farmers living in fragile ecosystems and socially unstable environments.

In Nigeria, cassava is produced by 24 states out of the 36 states that make up the federation (USAID, 2013), of which Cross river state according to Kingsley, Eucharia and Emmanuel (2014) remains one of the leading producers of the crop in the South - South region of the federation. According to FAO (2013) Nigeria currently produces about 54 million metric tons (MT) of cassava yearly making her the highest cassava producer in the world, producing a third more than Brazil and almost double the production capacity of Thailand and Indonesia. However, irrespective of the fact that Nigeria remains the world leading producer of cassava, the country according to Onyenwoke and Simonyan (2014) remains a dormant participant in cassava trade in the international market when compared to countries like Thailand and Vietnam that have become the major world exporters of cassava starch and chips.

The above predicament is attributed to the fact that the production and storage methods for cassava in Nigeria remains subsistent and traditional in the sense that the small scale farmers according to Oyebanji, Oboh, and Omueti (2003) accounts for 80% of cassava production in the country, and these farmers use old varieties and traditional production and storage technologies which largely account for low yield. This exposes fresh cassava roots to rapid post-harvest deterioration which according to Lyer et al, (2010) restricts the storage potential of harvested cassava roots to two to three days; which in turn substantially reduces the eating quality, transportation range, and financial value of cassava; thereby leading to a high level of discounting during marketing and sometimes discourages farmers from participating in marketing activities in distant locations.(Adebayo et al, n.d; Westby, 2002; Lyer Mattinson & Fellman, 2010). The above losses especially those emanating from post-harvest translate into low income and become a disincentive to investments and support for service provision in farming (World Bank, 2011). It also depletes the resource base used in production, and consequently influences the overall food available for consumption and export in a nation (Moomaw, Griffin, Kurczak & Lomax 2012).

Hence, reducing the above loss after harvest, especially in developing countries were around 310 billion US Dollars' worth of food is lost annually, can be a sustainable solution to increase food availability, reduce pressure on natural resources, eliminate hunger, and improve a nations ' living conditions without necessary increasing their production capacity (Barbara, 2019). Based on the above, authors such as Wheatley, Scott, Best and Wiersema (1995), Lyer et al. (2010) and Van Oirschot , O'brien, Dufour, EL-Sharkawya and Mesa (2000) all agreed that it remains pertinent to tackle fresh cassava root losses emanating from physiological postharvest deterioration (PPD) because it hinders the storage and marketing of fresh roots and also shortens the shelf life of the root, leading to wastage, poor products yield, economic losses, reduction in market quality and poor commercialization.

Each year, massive quantities of food are lost globally on its journey to consumers due to spoilage and infestations (FAO, 2011; Stuart, 2009). In 2018, more than 820 million people globally were not having enough to eat (SOFI/FAO, 2019); and this can be attributed to the fact that roughly, 1.3 billion tones (one - third) of food produced in the world for human consumption remains lost or wasted annually. Such losses especially in developing countries occur mainly at the early stages of the food value chain and can be traced back to financial, managerial and technical constraints in harvesting techniques as well as storage and cooling facilities (FAO, 2011). In line with the above, the obsolete storage technique of leaving cassava in the farm even after maturity (in-ground storage of the roots) remains the most predominant storage technique within the subsahara. The adoption of the above stated technique can be attributed to the fact that the crop when harvested is subject to rapid postharvest physiological deterioration (PPD), which reduces the shelf life and degrades its quality (Sánchez Dufour, Moreno, & Ceballos, 2006). This physiological deterioration is attributed to high moisture level (60 to 75 %, wet basis) (Salcedo et al. 2010), and high respiration rate of the crop ($\approx$23 μL CO_2/kg/h at 25 °C) (Aracena, 1993).

However, the adoption of the above storage technique poses a great threat to the cassava industry, because first it lignifies the cassava root due to long storage and also degrades the nutritional composition of the roots (Westby, 2002); also, it exposes the root to insects attacks and microbial infestation which consequently amounts to qualitative and quantitative food losses that hinders the effective commercialization of the crop. The above reason to a large extent remains responsible for the dormant contribution of Nigeria cassava industry in the international market.

This study will help in suggesting best storage mechanisms that are capable of reducing post-harvest losses among cassava farmers. Secondly, it will assist to reemphasis the various industrial raw materials that can be derived from cassava in order to ease the commercialization of the crop and also contribute to food security of Nations. Finally, this study would help fill the literature gap on the reduction of post - harvest loss for fresh cassava roots in Idomi.

Conclusively, to achieve the above, this study seek to literary review the extent to which storage mechanisms such as Waxing (which involves the use of paraffin wax in coating fresh cassava roots in order to extend its shelf life and ease marketability), field clamps (which requires building a clamp which consists of a layer of straw laid on a dry floor covered by a heap of sand), Storage in boxes lined with moist sawdust or wood shavings (which involves putting alternative layers of sawdust and cassava roots into a wooden box or create, then using saw dust to form layer s within the box were the fresh cassava roots are to be stored.) and storage in plastic film wraps/bags (which requires the application of fungicide on fresh and harvested cassava roots and then staking them in an air tight plastic bag or a plastic film wrap) can help extend shelve life and reduce post-harvest loss in fresh cassava roots.

Objectives of the Study

1. To examine the effect of waxing in the reduction of post - harvest loss for fresh cassava roots.
2. To examine the effect of Field Clamps in the reduction of post- harvest loss for fresh cassava roots.
3. To examine the effect of storage in boxes lined with moist sawdust in the reduction of post - harvest loss for fresh cassava roots.
4. To examine the effect of storage in Plastic Film Wraps / bags in the reduction of post - harvest loss for fresh cassava roots.

2. Literature Review

2.1 An Overview on Fresh Cassava Root Production and Harvesting

Cassava is a staple crop and a woody perennial shrub that can be cultivated throughout the year between latitude 30° N and 30° S, in different soil types except hydromorphic soil with excess water (Iyer et al. 2010). The crop is commonly propagated by stem cutting, the cuttings measuring 15–30 cm long with 4–6 nodes are used for planting. However, longer cuttings have been found to produce higher yield because they produce greater number of roots and shoot and contain larger stored food reserves that the plant can utilize before it becomes self-sufficient). Cassava cuttings are planted in different positions in various countries. The stems may be planted upright in a vertical position, inclined at an angle of 30–40 or horizontally at about 10 cm beneath the soil surface. When cassava stems are planted vertically, they sprout and acquire healthy foliage slightly more rapidly and produce deeper lying tubers than those inclined or horizontally planted. Cassava is usually planted when there is adequate moisture in the soil. This is important because young plants do not tolerate drought, unlike older plants. The crop is planted one cutting per hole/hill and sprouts within 7–14 days. It can be planted manually or with newly developed mechanical planters. The standard spacing is between 80 and 100 cm apart on ridges, mounds or flat which are 100–150 cm apart depending on cultivars and environmental conditions. The stem grows to about 5-m in height with each plant producing between 5 to 8 tubers with firm, homogenous fibrous flesh covered with rough and brownish outer layer of about 1-mm in thickness (Lyer et al. 2010). Several tubers are produced at growth stage and contain 35% starch and weighs up to 40 kg (El-Sharkawy, 2014). The first leaves appear by 10–13 days. After planting and the maximum leaf area is reached in 4–5 months. Flowering starts from the first 6 weeks and continues throughout the growth period of the crop. Tuber initiation starts from the 8th week after planting but depends on the variety and environmental conditions and most of the fibrous roots will develop into tubers from 6–9 months after planting thereby getting ready for harvest.

Cassava has flexibility in harvesting time and seasons (Haggblade et al. 2012). However cassava tubers should be harvested when they have not become firm or woody .It should be harvested at 7–15 months after planting depending on the cultivar. The sweet types are harvested around 7 months while the bitter varieties are harvested at about 12–15 months after planting. It is typically recommended that mature cassava should be harvested before the dry season starts to reduce the loss of tubers during the dry season when the soil is hard and dry. Cassava is usually harvested in piece-meals over a period after maturity. This means harvesting as the need arises. The crop can be harvested manually or using mechanical harvesters. For manual harvesting, cassava is mostly harvested by hand. In this process, the stem of the plant is cut of usually by using machetes, and then the remaining lower part of the stem is lifted out of the ground by hand. A mechanical harvester can also be used because it grabs onto the stem and lift the roots from the ground (Amponsah, 2014).

2.2 Meaning of Post-Harvest Loss (PHLs)

Postharvest loss remains one of the problems facing the agricultural sector in both developing and developed countries of the world. Post- harvest loss simply means the degradation in both quantity and quality of a crop from harvest to consumption. Post-harvest loss according to De Lucia and Assennato (2006) is the measurable quantitative and qualitative food losses in any postharvest system. Kitinoja, Saran, Roy and Kader (2011) defined PHL as the measurable qualitative and quantitative food loss along the supply chain. According to Boxall (2001) post-harvest losses can generally be classified as loss of weight due to deterioration, loss of quality, loss of nutritional value, loss of viability, and finally commercial loss. Based on the above definitions, it becomes pertinent to note that the size of losses after harvest in the food supply chain varies greatly depending on the crop, geographical area and type of economy. According to Barbara (2019), in developing countries, a society tries to make the best use of produced food; however, a significant amount of products is usually lost in operations after harvest due to lack of knowledge, inadequate technology for harvesting, transport technology, processing, and/or poor infrastructure. Conversely, in developed countries, the loss of food in the middle stages of the supply chain is relatively low, due to the availability of advanced technologies and more efficient systems of handling and storage of crops.

Despite these advantages, a large part of the food is lost at the end of the supply chain. In line with the above FAO (2011) maintained that in developing countries 40% of losses occur at post-harvest and processing levels while in industrialized countries more than 40% of losses happen at retail and consumer levels. Furthermore, Enoch, Stanslus, Susan, Kephas, Dietmar and Diego (2018) noted that post - harvest loss (PHL) comprises both food loss and food waste. Thus, food loss is simply the decrease in edible food mass throughout the part of the supply chain. Such losses are usually attributed to infrastructure and management limitations of a given food value chain. These types of losses usually takes place at the production, harvesting, primary handling, aggregation, storage, transport, processing, distribution, and consumption segments (FAO 2014). While food waste is the loss of edible food due to human action or inaction such as throwing away wilted produce, not consuming available food before its expiry date, or serving sizes beyond one's ability to consume.

2.3 Types of Post-Harvest Loss (PHLs)

Thorough literature research revealed that post - harvest losses can be group into two main losses. These loses are quantitative loss and qualitative loss (Hodges, 2012; Kwami & Nitty, 2014; Victor, 2014). Based on the above, the types of post-harvest losses commonly experienced are diagrammatically represented below:

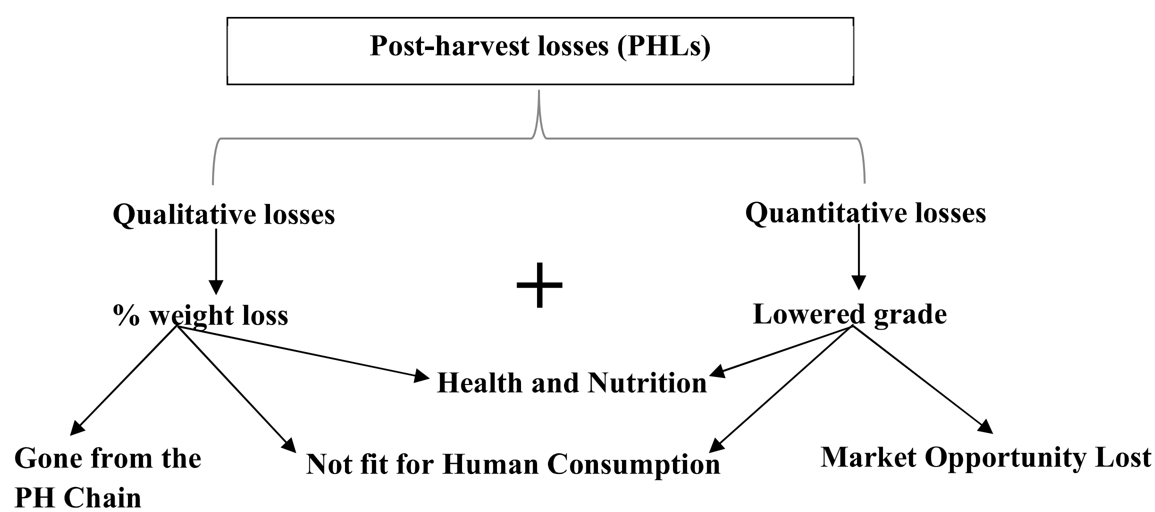

FIG 1: Description of post-Harvest Losses
Source: Hodges (2012).

From the diagram above, it remains obvious that qualitative and quantitative losses are the 2 major types of post-harvest loss experienced by agricultural produce; and as such, they are described below:

1. **Qualitative Loss**: Qualitative food loss is when food loses its quality attributes resulting in the deterioration in quality leading to a loss of economic, social and nutritional value. The qualitative loss can occur due to incidence of insect pests, mites, rodents and birds, or from handling, physical changes or chemical changes in fat, carbohydrates and protein, and by contamination of mycotoxins, pesticide residues, insect fragments, or excreta of rodents and birds and their dead bodies. When this qualitative deterioration makes food unfit for human consumption and is rejected, this contributes to food loss (Aulakhet al, 2013). In most cases, the quality deterioration goes along with a significant loss of nutritional value, which might affect the health and nutrition status of the whole community (FAO, 2014). In the FAO (2014) definitional framework of food loss working paper, qualitative food loss is simply defined as the decrease of quality attributes of food.

2. **Quantitative Loss**: Quantitative food loss refers to the decrease in edible food mass available for human consumption. In the FAO 2014 definitional framework of food loss working paper, quantitative food loss is simply defined as the decrease in mass of food. In physical terms, this is grain removed from the post-harvest supply chain and not consumed due to, among other causes, spillage, and consumption by pests and also due to physical changes in temperature, moisture content and chemical changes. The quantity lost would have either deteriorated rendering it inedible or discarded for failure to meet regulated standards to eat as a food or to use as an animal feed.

In summary, qualitative losses include those that affect the nutrient/caloric composition, the acceptability, and the edibility of a given product. These losses are generally more common in developed countries (Kader, 2002) while Quantity losses refer to those that result in the loss of the amount of a product. Loss of quantity is more common in developing countries (Kitinoja & Gorny, 2010). This loss especially in cassava can be attributed to the fact that Cassava roots according to Fadeyibi (2012) continues to respire after harvest and as a result, they are susceptible to deterioration and shortened/limited shelf life which in turn accounts for the reduction in market quality and poor commercialization of the crop (Van Oirschot et al. 2000). Based on the above, the various types of post-harvest deterioration for cassava are considered next in the study.

2.4 Post-Harvest Deterioration Associated with Cassava

Deterioration is a major challenge limiting the storage and marketing of cassava. This is because as soon as the root is uprooted from the ground, it begins a process of postharvest physiological deterioration within the next 24 hours (Amarachi, Oluwafemi & Umezuruike 2015). This deterioration which is often times characterized as a blue black discoloration of the root and the streaking of the xylem tissue limits the utilization of fresh cassava roots (Lyer et al. 2010). However, the early signs leading to this postharvest deterioration are not fully understood, but, Lyer et al. (2010) has attributed it to the increase in cellular respiration and the biochemical changes observed from 3 to 4 h after harvest. Therefore, according to Amarachi et al (2015) postharvest deterioration which generally causes spoilage and loss of harvested cassava root can be classified into physiological, microbial deterioration and mechanical damage.

1. **Physiological Deterioration:** The postharvest physiological deterioration (PPD) often known as primary deterioration has been assumed by Amarachi et al (2015) to be triggered by the breaks and cuts created on the roots during harvest or processing leading to the colour change on the roots. Often, there are cuts and bruises when the roots are pulled out of the ground and such areas forms the onset of deterioration (Reilly, Góomez-Váasquez, Buschmann, Tohme & Beeching 2004). This type of deterioration is not caused by microorganisms, but as a result of the mechanical damage and stress induced by water loss from wounds which therefore encourages the growth of microbes (Lyer et al. 2010). PPD is associated with colour change and the streaking of the xylem parenchyma tissue. This signs begin from the second day of harvest and has been likened to the normal biochemical and oxidative changes that occur as plants respond to wounds. Increased respiration of about 20 to 30 °C and low relative humidity between 65 to 80 % encourage deterioration (Sánchez et al. 2006). This implies that cassava root will still undergo deterioration and spoil even without any mechanical damage because of the aerobic respiration process which continues in the root even after harvest. In addition, oxidation is observed within 15 min from the part of the injured root leading to alteration in the genes and accumulation of the secondary metabolite (Reilly et al. 2004). Various techniques to reduce this postharvest deterioration have been investigated such as use of paraffin wax to coat each roots but this method could only extend and maintain quality of root for few weeks (Reilly et al. 2004). The exclusion of oxygen or submerging roots in water or storing in an anaerobic environment can inhibit the streaking of the xylem tissue. In addition, Van Oirschot et al. (2000) observed that pruning cassava plant 2 weeks before harvesting is another technique that reduces the susceptibility of this physiological deteriorative response of the root. Similarly, Sánchez et al. (2006) in their study on the effect of the total carotenoids content in cassava root on the reduction and delay of postharvest deterioration concluded that roots kept at 10 °C and 80 % relative humidity can remain fresh till after 2 weeks. Also, total amount of carotenoids in the roots is proportional to the rate of postharvest physiological deterioration in the root, this means that higher carotenoid can reduce or delay the onsets of PPD and extend the shelf life of the root, thereby broadening the industrial uses of cassava (Chávez et al. 2007).

2. **Microbial Deterioration:** Physical damage such as wounds, cuts and bruises (especially during harvesting, handling operations and transportation) can serve as focal points for microorganisms and lead to the second stage of cassava root spoilage known as the microbial deterioration or the secondary deterioration

(Falade & Akingbala 2010). Microorganisms that cause rotting induce microbial deterioration, and according to Onyimonyi (2002) they include Aspergillusniger, Aspergillusflavus, Aspergillusfumigatus, Penicilliumcitrinum and Rhizopus spp. Under aerobic conditions, these organisms cause a dry rot, which results in discoloration and a slight increase in acidity of the cassava root. Also, fungi attack on cassava product like chips has an influence on colour change, off-flavour and taste attributes (Gnonlonfin, Hell, Fandohan & Siame 2008). Also, under anaerobic conditions, deterioration is initiated by the activities of bacteria such as the Bacillusspp; this results in a rapid development of acid in the root (Onyimonyi 2002). The microbial deterioration of cassava root is characterized by fermentation and softening of the root tissue; this commences 4–5 days shortly after the primary deterioration from the wounded point (Buschmann et al., 2000; Reilly et al. 2004). This highlights on the importance of optimum postharvest handling practices, in order to minimize mechanical damage of the cassava root.

3. **Mechanical Damage:** Mechanical damage occurs as a result of careless handling when harvesting, transportation from the field to the processing site and during processing and peeling of the root (Iyer et al. 2010). Unfortunately, the effects of the injuries on the root are overlooked, but it has been attributed as the major factor constituting the physiological deterioration of the root (Fadeyibi 2012). In most cases, damages occur during harvest with the use of farm tools and machineries or in pulling of the root from the ground. The damages on the root during transportation could be caused by the vibration or compression in the packaging materials used. However, mechanical damage can be avoided through careful handling of root after harvest. Therefore, to minimize the effect of mechanical damage, once the root is harvested with cuts, the fresh root with cuts are subjected to a curing process for about 4 days under storage temperature between 30–40 °C and 90–100 % relative humidity (RH) (Fadeyibi 2012). The time for complete curing cannot be said certainly because it is determined by factors such as extent of wound, season, condition of the crop at harvest and the cultivars. The process has been seen as a means of reducing the onset of microorganism and disease as well as PPD and extending the shelf life of the fresh root.

2.5 Ways of Reducing Post–Harvest Losses

Oluwole (2008) noted that post - harvest loss can be reduced through the following ways:

1. **Harvesting:** Harvesting should be carried out as carefully as possible to minimize mechanical injury such as scratches, cuts and wounds this should be carried out during the cool part of the day, which is early morning and late evening. Careful digging and movement of roots during harvesting significantly reduces post - harvest losses.
2. **Handling:** Mechanical injury provides sites for pest attack and increases physiological losses. Therefore, avoid mechanical injury to the crop while handling. Crops should be handled gently to minimize bruising and breaking of the skin. Bruising renders the product unsalable to most people although it usually has minor effect upon the nutritional value. The brown skin peel of

cassava root is an effective barrier to most of the opportunistic bacteria and fungi that cause rotting of the tissues. Breaking of the skin also stimulates physiological deterioration and dehydration. Thus, reducing the number of times the commodity is handled reduces the extent of mechanical damage and as such cassava after harvesting should be transferred promptly to a clean, cool, well-ventilated shed.

3. **Sorting and Cleaning:** Sort out damage crops from undamaged crops in order not to contaminate the undamaged cassava roots through exposure to microbial agents.
4. **Transportation:** Load and unload transport vehicles carefully. Use clean, well-ventilated vehicle covered at the top for transportation. Transport crops during the cool part of the day by driving carefully over smooth roads to minimize damage to crop.
5. **Storage:** Only crops with high initial quality can be stored successfully, it is therefore essential to ensure that only crops of the highest quality (mature, undamaged) are stored. Separate damaged crops from wholesome crops and dispose of the damaged crop quickly in order to avoid deteriorations emanating from microbial agents. Storage remains a key in the reduction of postharvest loss especially in cassava because it increase the shelf life of cassava from when it is harvested till when it is either processed or marketed.
6. **Establishment of Marketing Cooperatives**: the establishment of marketing cooperatives especially in developing countries would help provide central accumulation points for harvested cassava products that would act as an acute selling point linking small cassava producers to large market.

2.6 Conceptual Model

The conceptual model below proposes storage mechanisms that are capable of reducing the post- harvest loss for fresh cassava roots.

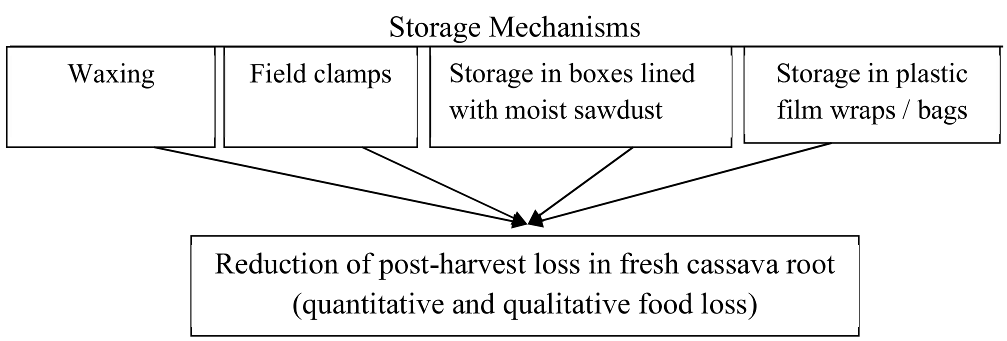

FIG 2: Conceptual Model
Source: Developed by the Researcher

From the conceptual model above, it is opined that proposed storage mechanisms such as waxing, field Clamps, storage in boxes lined with moist sawdust and storage in plastic film wraps / bags remains capable of reducing the quantitative and qualitative loss in fresh cassava roots in Idomi, Yakurr

Local Government Area of Cross River State, Nigeria. The suggestion of the above listed storage methods is a s a result of the fact that in Idomi, the traditional in ground method of storage were cassava roots are left in the farm even after maturity have remained the dormant practice and have to a large extent lignifies the cassava roots as well as exposes fresh cassava roots to theft, attack by rodents, insects and microbial infections which in turn increases the qualitative and quantitative loss of the crop. Based on the above, the proposed storage mechanisms used in the storage of fresh cassava roots are considered below in an exploratory manner.

2.6.1 Waxing and the Reduction of Post-Harvest Loss

Waxing remains one of the improved storage technique for the preservation of fresh cassava roots. It was developed by the Centro Internacional de Agricultura Tropical (CIAT) Palmira, Colombia, in conjunction with National Resources Institute (NRI), Chatham, UK (Fadeyibi 2012). This method according to Atanda, Pessu, Agoda, Isong and Ikotun (2011) remains a storage technique that can be used on a number of commodities like fruits, cucumbers cassava etc. because it retards the rate of moisture loss and maintains turgor and plumpness and may modify the internal atmosphere of the commodity. The wax primarily offers a cosmetic effect and imparts a gloss to the skin and gives the produce a more shiny appearance than the unwaxed commodity. Waxing of fresh cassava roots has been shown to reduce spoilage in fresh roots by up to 50%, within the first 14 days after harvest (Zidenga et al., 2012). Waxed roots after harvesting can be transported more easily over longer periods of time, and hence, can be sold as a premium product in high-end markets such as urban areas and supermarkets, or for export (Wanda et al., 2014). Application of wax could be used to reduce spoilage even on an industrial scale (Simonyan, 2014). A Preliminary experiments towards preserving fresh cassava roots by coating them in wax was carried out in India. The wax contained a fungicide and the roots were dipped in it to coat them Storage duration could be extended to about 10 days with weight losses amounting to 10% (Rickard & Coursey, 1981). In Columbia an experiment was conducted in which fresh cassava roots were simply dipped in paraffin at a temperature of 90° - 95°C. Without any fungicide being used, the storage duration was extended from 2 to 3 days up to about 30 days by preventing discolouration in the vascular tissue of fresh cassava (Buckle et al., 1973). In summary, the use of wax has been reported to prolong shelf-life of cassava roots up to 2 months (Ravi et al., 1996; Aristizabal & Sánchez, 2007). But however Africa has not fully exploited the waxing technology as a shelf-life improving technology for root and tuber crops (Wanda et al., 2014). The above according to Fadeyibi (2012) can be attributed to the fact that this method is expensive to maintain and the equipment used for the purpose requires skilled personnel.

2.6.2 Storage in Field Clamps and the Reduction of Post-Harvest Loss

This method of storing fresh cassava roots is often times regarded as a traditional method because field clamp structures are similar to old European potato clamps. In this storage method, clamps are constructed by making a circular bed on the ground and laying straws or other materials such as dried grass or dry sugar cane leaves on the floor, and subsequently arranging the roots layer by layer on the compacted straws which usually is approximately 1.5 metres in diameter and 15.0 centimetres in thickness. The pile of roots is then covered with similar straw, and the entire clamp which is done on a dry ground is then covered with soil to a thickness of 15 centimetres. The soil is then removed from around the circumference of the clamp, forming a drainage ditch and holes for ventilation. This storage method according to Booth (1975) is usually done in consideration to prevailing climatic conditions in a particular area and time. This is because in hot, dry conditions, it is necessary to ensure that the internal clamp temperature does not exceed 40°C since roots deteriorate rapidly at higher temperatures. To Booth (1975) the condition of the clamp can be altered during hot seasons by providing a thicker soil cover to reduce the internal temperature and the provision of ventilators so as to encourage air flow within the clamp. Ventilators may be constructed from locally available materials such as straw, hollow bamboo, drainpipes, or timber. In very wet conditions. Precautions need to be taken to prevent the roots from becoming wet within the clamp since wet roots deteriorate rapidly. Furthermore, frequent light rainfall tends to be advantageous after clamp formation because moistening of the soil lowers the internal temperature of the clamp.

But however, during very wet conditions roots that were rained upon during harvesting and handling should not be stored even if they were subsequently sun dried because such condition result to rapid roots deteriorate. Based on the above, an experiment conducted by Tropical Products Institute (TPI) and the Centro Internacional de Agricultura Tropical (CIAT) in Columbia to ascertain the effectiveness of field clamp storage in storing 300 to 500kg of fresh cassava roots revealed that fresh cassava roots can be stored up to a periods of up to 4 weeks using this method. According to Booth, (1975) the Losses experienced in weight and the formation of rot were low.

Furthermore, Booth (n.d) re investigated the effectiveness of flied clamp storage in the storage of fresh cassava roots of which several clamp units were built at C.I.A.T. from November 1972 to June 1973. Each clamp was built, on well-drained ground, by first placing a circular bed of rice straw of 1.5 m diameter and of sufficient thickness so that, when later compacted, it was approximately 150 mm thick. Five hundred roots were heaped on this straw in a conical pile. These roots weighed approximately 300 kilos. Unselected roots were used, so that there was a large variation in root size and a substantial proportion of roots were mechanically damaged. The pile of roots was then covered with straw which compacted to a layer 150 mm thick. The whole clamp was then covered to a thickness of 100-150 mm with soil dug from around its circumference so as to form a drainage ditch. Storage clamps were opened and the roots examined after periods of one, two and three months. During cooler periods or during periods of frequent but light rainfall, the roots were successfully stored, with an acceptable level of loss, for two months. During such periods the temperature inside the clamps was between 300C and 35°C. This temperature was found to remain constant throughout the storage periods, whereas the temperature of the soil cover fluctuated with the day and night temperature variations. A large proportion of the stored roots were successfully cured, and there was visible evidence of wound healing after one month in storage. After two months storage, the bulk of the roots remained undeteriorated. However, a few of the stored roots, although remaining undiscoloured, had softened in the centre. After three months storage, the percentage of unmarketable roots had increased considerably as there was some central softening in otherwise undeteriorated roots.

Conclusively, Booth (1975) maintained that Field clamp storage has showed that cassava roots can be successfully stored for a period of one to three months, depending on clamp design and prevailing ambient conditions. The above conclusion emanated from the fact that field clamps irrespective of size and cross sectional design do have the potential of extending the shelf life of fresh cassava roots.

2.6.3 Storage in Boxes Lined with Moist Sawdust and the Reduction of Post-Harvest Loss

In this storage method Cassava roots are packed in boxes containing adsorbent material such as sawdust (Rickard & Coursey, 1981). According to Osunde and Fadeyibi (2011) this method involves putting alternative layers of sawdust and cassava roots, starting and finishing with a layer of sawdust. As an alternative to sawdust, wood shavings or any other suitable packing material can be used. However, the packing material must be moist but not wet because physiological deterioration occurred if the material becomes too dry and microbial decay will be accelerated when it becomes too wet. Thus, the box according to Fadeyibi (2012) should always be monitored and water applied when necessary (Fadeyibi, 2012). In Uganda this storage method was tested in combination with the lining of box with plastic (Nahdy & Odong, 1995). The study indicated that 75% of the roots remained healthy after four weeks in store, provided the roots were packed immediately on the day of harvest. With a delay of one day only 50% of the roots were rated as acceptable. This technique has been used for some export markets but the higher transport cost involved because of the box containers has precluded its use for domestic market (Osunde & Fadeyibi, 2011).

In Ghana this method of storage was modified and the crates (boxes) were replaced by large baskets. The baskets were lined with fresh banana leaves which also served as a cover for the stored produce. Before storing the roots these were subjected to three days of curing. Storage periods in Ghana using this method reached 2 months (injured and cured roots) and up to 6 months (uninjured roots) (Osei-Opare, 1990).

In Nigeria, Olaleye, Otunola, Oyebanji, &Adetunji (2013) investigated the effectiveness of trench and sawdust storage in maintaining moisture content of cassava root. They observed that the root stored at ambient temperature using both methods showed high level of water retention up to the sixth week of storage. This is a clear indication of the good keeping quality of freshly harvested roots (Karim, Fasasi, & Oyeyinka, 2009). However, the limitation of these techniques is that the high relative humidity in the storage environment could inhibit the growth of microorganisms (Olaleye et al. 2013).

Conclusively, this storage method has proven to reduce post-harvest loss for fresh cassava roots for up to 6 weeks and as such it can be adopted where fresh cassava roots are sold over long distances because it allows sufficient storage ability and also reduces the risk of early deterioration.

2.6.4 Storage in Plastic Film Wraps / Bags and the Reduction of Post-Harvest Loss

This storage method according to Osunde and Fadeyibi (2011) was developed by the Centro Internacional de Agricultura Tropical (CIAT) and it involves harvesting and selecting high quality, relatively undamaged roots from cassava varieties. The roots are washed or cleaned and then dipped or sprayed with a fungicide, (thiabendazole) which is widely used as a post-harvest treatment for banana and potato. The drained roots are then placed in polypropylene bags that are sealed. The respiration of the roots within the bag causes the relative humidity (RH) of the enclosed atmosphere to rise. The high RH in combination with a temporary holding of the bagged roots at high temperature causes root curing which promotes an extension of shelf life of the roots (CIAT, 1989). This storage method according to the Centro Internacional de Agricultura Tropical (CIAT, 1989) shows promise in the reduction of postharvest losses of fresh cassava roots.

In line with the above Osunde and Fadeyibi, (2011) maintains that a number of studies have shown that cassava roots treated with an appropriate fungicide and kept in an airtight plastic bag or a plastic film wrap can be stored for two to three weeks. According to Best (1990), the adoption of this method in Columbia preserved the fresh cassava root for a storage duration of more than 14 days.

In Tanzania, this method was tested in several villages in Coast region and two urban markets in Dares Salaam by TFNC and NRI, after which a flexible dissemination strategy was developed and applied to other villages. In a case study carried out at the same time, it was shown that successful adoption of the technology would improve the quality of cassava reaching the urban consumers and contributes to poverty alleviation by improving the income generating potential of fresh cassava marketing. In Ghana, this method was adopted but no fungicide was applied rather fresh and healthy cassava roots were simply dipped in water and maintained at high humidity and put into polyethylene bags.

The result revealed that the method extended the useful shelf-life of the fresh cassava roots for a period of 7 – 10 days.

In conclusion, Studies according to Amarachi et al (2015) have proven that the storage of cassava root up to 2 weeks in plastic airtight films remains possible. Also, treating the root with fungicides like thiabendazole for few seconds before packaging in the polymeric film could extend the shelf life of the root. Hence, this method could favour commercial exportation of cassava root.

2.7 Empirical review

The development of storage infrastructure has been opined by scholars as possible ways of reducing the rapid post- harvest loss associated with fresh cassava roots. In line with the above, a study conducted by Adebayo et al, (n.d) on extending the shelve life of fresh cassava roots for increased incomes and post - harvest loss reduction revealed that storage techniques such as storage in cool and humid conditions especially in polyethylene bags after spraying with fungicide as well as waxing of the fresh cassava roots with paraffin wax were capable of reducing the post- harvest loss of fresh cassava roots in Uganda. In line with the above finding, Amarachi et al (2015) maintain that waxing cassava roots through the use of paraffin wax also creates the possibility to market the crop and further increase the margin of holding stock of fresh root for a period of two weeks.

Furthermore, a review conducted by Amarachi et al (2015) on post -harvest handling and storage of fresh cassava rot and products revealed that the storage of fresh cassava roots through the use of field clamps has the capability of extending the shelve life of fresh roots for a period of 8 weeks.

Olaleye et al. (2013) investigated the effectiveness of storages in boxes lined with saw dust and trenches in maintaining moisture content of cassava root. They observed that the root stored at ambient temperature using both methods showed high level of water retention up to the sixth week of storage, which according to Karim et al. (2009) is a clear indication of the good keeping quality of and postharvest of freshly harvested roots. However, the limitation of these techniques is that the high relative humidity in the storage environment could inhibit the growth of microorganisms (Olaleye et al. 2013).

Conclusively, a study conducted by Nahdy and Odong, (1995) on the Storage of Fresh Cassava Tuber in Plant based Storage Media, revealed that Storage in Boxes Lined with Moist Sawdust or Wood Shavings has the potential of keeping 75% of the roots healthy after four weeks in store, provided the roots were packed immediately on the day of harvest. Moreso, According to Best (1990) the adoption of this method in Columbia preserved the fresh cassava root for A storage duration of more than 14 days.

2.8 Theoretical Framework

2.8.1 Theory of Constraints (TOC)

The theory of constraints (TOC) remains an overall management paradigm that views any manageable system as being limited in achieving more of its goals by a very small number of constraints. This theory was developed by Eliyahu M. Goldratt in 1984 in his book titled The Goal. The key assumption of this theory is that every process has a single constraint and that total process throughput can only be improved when the constraint is improved. A very important proposition to this is that spending time optimizing non-constraints will not provide significant benefits; only improvements to the constraint will enhance the accomplishment of the goal. Based on the above this theory according to Zeynep, Noyan and Özalp (2014) focuses on identifying the most important limiting factor or the weakest link in the chain (i.e. constraint) that stands in the way of an organization in its quest to achieve a set goal and then systematically improve that constraint until it is no longer the limiting factor. A constraint is anything that prevents the system from achieving its goal. These constraints can either be internal or external to an organization system. According to Cox, Mabin and Davies (2005), The theory of constraints considers focus to be the underlying power of the theory because the theory urges organizations to focus on a single goal and to remove the principal impediment (the constraint) that hinders it from achieving more of that goal. In line with the above preposition, the five focusing steps of the theory of constraints are diagrammatically shown below:

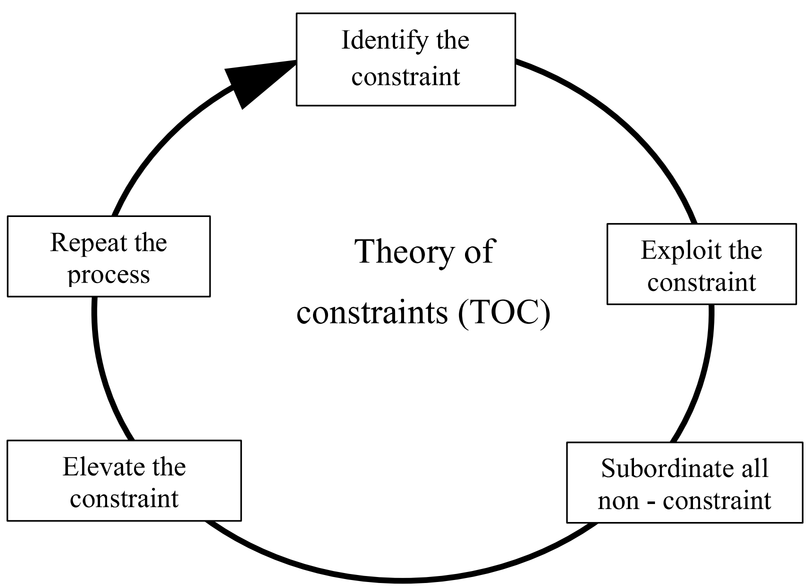

FIG 3: Showing the five Focusing steps of Theory of Constraint
Source: Leansixsigma.Community.

The above five focusing steps of the theory of constraints are used in identifying and eliminating constraints in an organization. Based on the above the Five Focusing Steps are further described thus; the first step is to identify the constraint which happens to be the single part of the process that limits the rate at which the goal is achieved. The second step is to exploit the constraint by deciding how best the constraint can be tackled because the constraint is often times not considered as a problem but an opportunity which can be unscrambled through tactical planning. The third step is to subordinate all non-constraints in order to focus on the core constraint that impedes the achievement of the set goal. The fourth step entails elevating the constraint. This is common when the first three steps fail to resolved the constraint. This step may often time require extra resources in terms of more machines, more employee etc, to overcome the constraint. The last step is repeating the process, this is because once a particular constraint is been eliminated, the organization identifies another in order to ensure continuous improvement.

Hence, the application of this theory to the study remains obvious because the major constraint that has been identified to have hindered the commercialization of fresh cassava root especially in developing countries like Nigeria has remain the rapid postharvest physiological deterioration (PPD) that has limited the shelf life of fresh cassava roots to 72 hours after harvesting. Such deterioration substantially reduces the eating quality, transportation range, and financial value of cassava (Booth, 1976; Buschmann, Rodriguez, Tohme & Beeching 2000; Westby, 2002; Lyer et al., 2010).Once this constraints is remedied with adequate storage infrastructure it would to an extent reduce food loss and wastage within the country, and also increase the availability of cassava produce for exportation thereby improving the status of Nigeria within the international cassava market.

3. Conclusion

Cassava remains an important food crop to a number of communities in Nigeria with Idomi inclusive as it serves as a primary carbohydrate source in their diets; while still contributing to food security and incomes for rural communities. Based on the above, the crop is currently undergoing a transition from a mere subsistent crop found on the field of peasants to a commercial crop grown in plantations. The unprecedented expansion of this crop is attributed to its discovery as a cheap source of edible carbohydrate that could be processed into different forms of human delicacies and animal feeds. Hence, Cassava is to African peasant farmers what rice is to Asian farmers or wheat and potatoes are to European farmers. However, irrespective of the importance attached to this crop and the large production capacity within the Nigerian terrain, the commercialization and marketing of this crop both at the regional and international markets remains hindered by the rapid post - harvest deterioration associated with the crop. Thus this rapid post-harvest deterioration of the crop which usually begins 2days after harvest exposes the crop to a high significant post - harvest loss if in adequate storage mechanisms or infrastructure are not available to extend the shelve life of harvested cassava roots.

Hence, this study in conclusion opines that storage mechanisms such as waxing, field clamps, storage in boxes lined with moist sawdust and storage in plastic film wraps / bags when properly adopted in Idomi can help in the reduction of post - harvest loss for fresh cassava roots by extending the shelve life of the crop maximum 72 hours to a period of 2-8 weeks thereby promoting the marketing and commercialization of the crop.

4. Recommendations

Based on the above findings and conclusion, the following recommendations are preferred

1. The storage techniques (waxing, field clamps, storage in boxes lined with moist sawdust and storage in plastic film wraps / bags) should be introduced to cassava farmers in Idomi in order to enable them increase the shelve life of harvested cassava roots and reduce the high post harvest loss associated with the crop.
2. Agricultural extension workers should be deployed to Idomi community and other cassava producing community in Nigeria by the Ministry of Agriculture to help train cassava farmers on the use of the storage mechanisms (waxing, field clamps, storage in boxes lined with moist sawdust and storage in plastic film wraps / bags) as against the traditional in ground storage that is practiced in the area.
3. Agricultural Marketing co-operative should be formed in order to educate farmers on value addition to harvested cassava roots through post - harvest handling, processing, storage and marketing.
4. A collective supply chain should be formed by cassava farmers in order to encourage adequate commercialization of the crop to urban markets.
5. Community mobilization through persuasive communication and the use of African traditional media such as town criers, storytelling etc, should be adopted in order to ease the diffusion of the storage techniques within the community.

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